GEOTHERMAL GUIDELINES FOR MUNICIPALITIES:

Regulations and Drilling Primer

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Prepared by:

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EXECUTIVE SUMMARY

Geothermal (Ground Source Heat Pump) systems are the most energy efficient heating and cooling systems available today. They play a critical role in decarbonizing the built environment in Ontario and globally. Geothermal heat pumps have been shown to have lower peak electrical requirements than alternative air source heat pumps[1,2].

This document provides a primer on geothermal systems including basic information on how they work; the types of systems available; and regulations currently in force. It discusses the challenges and obstacles to large-scale adoption of geothermal systems across the province including financial, technical and regulatory requirements.

The primary intent of this document is to provide a set of regulation recommendations that can be adopted by municipalities who do not currently have geothermal regulations in place. A harmonized interpretation of the Building Code and referenced standards is crucial to successful and timely implementation of geothermal systems in all regions of Ontario. A framework set of recommendations for the approval process for all authorities having jurisdiction is presented in section 4.7 of this report. This framework is based on implementations already in place in some jurisdictions in Ontario.

The target audience for this document is anyone involved in the adoption or regulation of geothermal heat pumps and building systems. This includes:

- Municipal government officials looking for context to adopt Green Building Standards.
- Authority having jurisdiction officials involved in the approval process for geothermal systems including those tasked with:
    - Protection of drinking water aquifers
    - Building permitting
    - Environmental protection
- Government policy makers
- Industry professionals including: designers, engineers, and consultants

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[1] https://ontariogeothermal.ca/downloads/dunsky--hrai-benefitsofgshps--2020-10-30-.pdf

[2] https://info.ornl.gov/sites/publications/Files/Pub196793.pdf

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1 INTRODUCTION

1.0 The Transition to Global Decarbonization

After decades of debate on climate change, Canadians are joining the majority of worldwide governments to transition from a fossil-fuel economy to a clean energy future. Canada's greenhouse gas emissions have declined 8.4 percent from the 2005 baseline[4]. Over the next three decades, our society will witness the end of the fossil-fuel era. A move to global decarbonization is about to begin.

Ontario requires a carbon-free electrical grid to reach global decarbonization goals. As Rural areas are harnessing wind and solar energy; car manufacturers are rolling out fleets of electric vehicles; and finally, the building sector, which consumes about one-third of society's total energy demand, has entered the decarbonizing challenge[5]. After reducing the electricity grid emissions substantially between 2007 and 2017, the Ontario grid is projected to see a gradual increase in GHG emissions[6]. Electrification of the Ontario build stock relies on reducing the GHG emissions from the electricity grid and it is well understood this trend needs to reverse.

The GTHA (Greater Toronto and Hamilton Area) has, by far, the largest concentration of buildings in Canada. Until now, most of these buildings have been heated with fossil fuels. Natural gas pipelines have been (and continue to be) installed in virtually all parts of the GTHA. Our society has become used to fossil-fuel space heating during the fall, winter and spring seasons. We heat our homes, farms, offices, schools, public buildings, industries and domestic hot water with natural gas. We now recognize that heating buildings have become one of the most significant GHG (greenhouse gases) sources in the GTHA.

During the past few decades, indoor cooling during the summer months has become the norm. The entire GTHA cooling energy load is supplied by electricity. This has resulted in the summer peak electrical demand being much greater than the winter peak demand.

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[4] https://www.pembina.org/blog/national-inventory-report-suggests-canadas-climate-policies-are-starting-work

[5] The pace of decarbonization has increased rapidly in recent years. In the short time of writing this document, the tense of this phrase has changed from "entering" to "entered".

[6] Ontario Clean Air Alliance, Getting Ontario to a Zero-Carbon Electricity Grid by 2030, February 2022. https://www.cleanairalliance.org/wp-content/uploads/2022/03/Zero-Emissions-Report-2022-feb-25-v_02.pdf

The first steps to reduce our reliance on fossil-fuel heating and electrical consumption for cooling have already been taken by the City of Toronto. The Toronto Green Standard (TGS) was implemented in 2006 to upgrade the building code requirements for the building sector[7]. It calls for a gradual transition to zero-emission buildings by 2030. In addition to the City of Toronto, a number of GTHA municipalities have implemented green development standards (including Halton Hills, Markham, Brampton, Vaughan, Whitby and Ajax).

1.1 The Building Sector Energy Demand

Previously, heating our buildings with natural gas (supplemented by electrical energy) was relatively inexpensive and convenient. There was little incentive or building code requirements to improve energy efficiency in the building sector. It was usually cheaper to burn more fossil fuels for heating than to retrofit a leaky building. The past half-century has also seen a universal shift in society's demand for home and workplace cooling. Commercial-scale cooling is common in our shopping centres, schools, workplaces and residential towers. The dramatic increase in cooling load is the primary reason for the gradual shift from winter to summer peak of the electrical demand in most urban communities in Ontario.

Population growth in the GTHA was the highest among the ten most populous metropolitan areas in North America from 2018-19[8]. This growth is not expected to change in the coming years. At this pace, it won't take many decades to double the existing building stock. Phasing out the use of fossil fuel heating will need to be accomplished in this period of high growth.

Decarbonizing the existing and future building stock will require two major initiatives: improved building energy efficiency and a switch to renewable energy sources. All buildings will have to be more efficient in heating, cooling, ventilation and equipment. In the next few decades, fossil-fuel heating will need to transition to renewable heating sources. This movement will trigger the need for energy efficiency throughout the building sector.

1.2 The Steps to Carbon Reduction

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[7] https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/toronto-green-standard/
[8] https://www.ontario.ca/document/ontarios-long-term-report-economy/chapter-1-demographic-trends-and-projections#:~:text=Under%20all%20three%20scenarios%2C%20Ontario's,million%20on%20July%201%2C%202046.

Carbon reduction in the GTHA will be triggered by the TGS and federal and provincial building code requirements to improve the building sector's energy efficiency. The high heat loss in buildings from the fossil fuel era will not be tolerated in the future. Since today's buildings will last for decades, they must be future-proofed for the time when renewable energy replaces fossil-fuel energy.

The steps to carbon reduction in the GTHA have already started. Targets have been set. A roadway to reduce buildings' heating and cooling loads is in place. All levels of government are making commitments to meet the Paris Agreement objectives for the building sector.

The GTHA will generally experience an increase in electrification and a gradual transition from fossil fuel to renewable energy. While wind and solar energy will supplement Ontario's electrical demand, geothermal energy will lead the way to replace natural gas for space heating in buildings. Geothermal is a unique energy source that can also reduce the electrical demand for space cooling.

2 GEOTHERMAL HEATING AND COOLING BACKGROUND

2.1 Holy Grail

In his book “Kick the Fossil Fuel Habit,” author Tom Rand described geothermal energy as the “Holy grail of heating and cooling buildings.” He demonstrated that geothermal energy was viable for heating and cooling buildings in 2010. His initiative set the stage for a decade-long acceleration of geothermal energy throughout the GTHA.

Geothermal energy is stored in the earth and groundwater beneath every property in the GTHA and throughout the province. The subsurface temperatures to a depth of 300 metres are relatively constant throughout the year. With the help of electrically-powered heat pumps, the geothermal energy in the earth’s crust can be harnessed to heat and cool the entire building sector.

While geothermal energy can provide a constant carbon-free energy source, careful management of the systems is required to take advantage of the low-temperature heat. For example, the buildings' annual heating and cooling energy loads should be relatively balanced. Otherwise, there would be a risk of overheating or overcooling the earth and groundwater below the building.

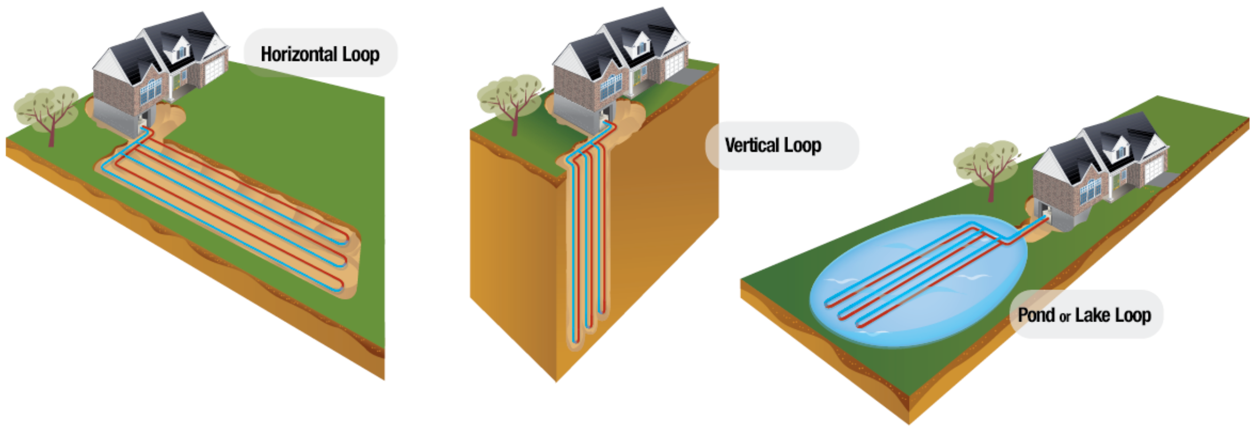
2.2 Geothermal Basics

Geothermal systems harness the thermal energy stored in the upper 300 m of the earth’s crust. Heat pumps must be used to amplify earth and groundwater temperatures of 8 to 12°C. In the winter, the heat pump acts like a furnace, boosting the ground temperatures enough to heat the building. In the summer, the heat pump works like a refrigerator to extract the building heat and inject it into the ground.

There are typically two common geothermal options in denser urban areas: vertical closed-loop boreholes and open-loop water wells. The latter system is only feasible in limited areas that are underlain by a major aquifer. Depending on site conditions, horizontal and surface water systems may be viable in rural areas. Other geothermal systems that have limited application include:

- Horizontal closed-loop systems for large rural properties;
- Open and closed-loop systems for properties fronting on deep rivers, lakes and ponds;
- Building dewatering systems that currently discharge water to sewers or streams;

- Standing column wells for sites located above deep bedrock formations with good quality; groundwater but limited groundwater supplies; and
- Abandoned mines.



Most geothermal installations are for space heating and cooling of buildings. Other applications include the following:

- Snow melting and de-icing
- Domestic hot water (DHW) heating
- Greenhouses that operate year-round
- Farm and manufacturing operations
- Agricultural drying and food processing
- Heating and cooling mining operations

Ontario's most common geothermal system involves coupling low-grade thermal energy from the overburden and bedrock formations in the upper 300 m of the earth's crust. This energy source is primarily stored solar energy as the temperature at these depths is normally the average ambient temperature. The ground temperature increases with depth as heat from the earth's core diffuses to the surface. The geothermal energy is harvested by inserting HDPE (high-density polyethylene) U-loops into deep drilled boreholes.

The geological conditions at each project site dictate the constructability of the geothermal boreholes. These are never fully known until test boreholes are drilled. The test boreholes identify the site geology and groundwater conditions and can be used to measure the thermal properties of the borehole materials.

The geology in Ontario includes a wide range of bedrock formations, as well as complex overburden deposits. Each combination of overburden, bedrock and groundwater may require different drilling methods. A brief overview of the basic geological considerations is given below:

- Igneous rocks
    - "Hard" rock formed by molten rock and lava crystallization.
    - An example is granite.
- Sedimentary rocks
    - "Soft" rock formed by hard rock erosion, followed by heat and pressure crystallization.
    - Examples include limestone, dolostone, sandstone and shale.
- Metamorphic rocks
    - Rock formed by recrystallization by intense heat and pressure.
    - Examples include gneiss and marble.
- Glacial till deposits
    - Dense, stony overburden with a high clay content.
- Glacial outwash deposits
    - Permeable sand and gravel deposits laid down during the recession of the last glaciation period.

The thickness of the unconsolidated overburden deposits ranges from zero to about 200 m. Maps are usually available from government agencies that show the overburden thickness. Geologic cross-sections are often available that show the sequence of overburden deposits.

The distribution and stratigraphy of bedrock formations across Ontario are also available from government agencies. The "softer" sedimentary formations are found mostly in the southwestern parts of the province. The "harder" igneous and metamorphic formations are found mostly in the Canadian Shield areas throughout much of northern Ontario.

In the Toronto area and most of southwestern Ontario, the sedimentary bedrock formations are usually greater than 300 m thick. The full sequence of sedimentary rock usually includes multiple formations, including shale, limestone, dolostone and sandstone.

The drilling depths for closed-loop boreholes have gradually increased over the past 20 years. This increase is due to the desire of geothermal owners to maximize the energy capacity of their systems. The deepest drilling in the Toronto area is 260 m, and the deepest in the Ottawa area is 300 m. In these cases, the borehole fields penetrate the full thickness of overburden and terminate in the underlying bedrock formations. Many smaller systems in the province are drilled exclusively in unconsolidated soils above the bedrock.

The deep earth temperature usually reflects the average annual air temperature of the site. For example, earth temperatures in Ottawa and much of Northern Ontario typically range from 8 to 9°C, while the bedrock temperatures in Toronto and southwestern Ontario usually range from 10 to 12°C. The thermal properties of the overburden and bedrock formations, combined with the in-situ temperatures, are key factors in designing closed-loop systems.

Two main constraints for closed-loop drilling in Ontario are gas-producing bedrock and artesian (i.e. flowing well) conditions. In each case, drilling programs must proceed cautiously to prevent hazardous drilling conditions. Both gas formations and artesian conditions are generally well-known in Ontario.

2.3 Development of Geothermal

The harnessing of geothermal energy is not new in Canada. The earliest reported systems were developed in the Winnipeg area 100 years ago. By the mid-20th century, the Ontario dairy and manufacturing industries were drilling wells for groundwater cooling operations. Ontario communities started installing high-capacity wells to cool manufacturing operations.

In the 1980s, Canada was leading in developing an aquifer thermal energy storage (ATES) system that was first discovered in China. The ATES technology involves the artificial heating or cooling of an aquifer by injecting water into it. A decade of research at the Canada Centre office tower in Scarborough and Carleton University, Ottawa, was done to demonstrate this unique system. The two projects showed that warm groundwater rejected after cooling the buildings could be stored in aquifers for heating the buildings the following winter. Similarly, cool water rejected from winter heating can be stored for cooling the building in the summer.

In 1949, Professor Frank Hooper at the University of Toronto started pioneering geothermal heat pump technology research. His first research paper, released in 1951, concluded that "*ground coils in suitable soils offer a satisfactory heat source in Ontario*." It took another 30 years to progress the technology to become a commercially suitable option to heat and cool buildings effectively.

Drilling programs in the 1980s discovered that earth temperatures to depths of up to 300 m were constant, ranging from 8^{o}C in northern Ontario to 12°C in southern Ontario. With the help of heat pumps, Swedish researchers discovered that the stored geothermal energy in the earth could be harnessed by circulating fluids through plastic U-loops in drilled boreholes.

In the early 2000s, the first large-scale closed loop borehole system in Canada was installed at the UOIT campus in Oshawa. It consisted of nearly 400 water-filled boreholes drilled to a depth of 200 m. It soon became apparent that geothermal energy could be mined anywhere without groundwater aquifers. As a result, closed-loop technology quickly overtook the open-loop opportunities in Ontario.

The last two decades have witnessed rapid growth in the closed-loop industry. Customized drill rigs have been developed to allow production drilling. The drilling depths have increased from 100 m to 300 m. The size of the borehole fields has also increased from a few dozen in the early 2000s to several hundred in the 2020s. The closed-loop industry has expanded from primarily residential installations at the turn of the century to high-rise buildings and university campuses.

Starting in the late 2010s, the open-loop water well industry saw a resurgence in the commercial and institutional sectors. A key driver of this resurgence is the increased regulation and protections around regions which rely on ground water for drinking water. An open loop system relies on fewer penetrations into groundwater aquifers than a closed loops system and they can be designed to include contamination monitoring. This geothermal option is only viable in areas of the province underlain by major aquifers.

2.4 The Myths About Geothermal Energy

Like any new technology, many misconceptions have evolved regarding the use of geothermal energy. Most geothermal myths have developed because it is an unseen renewable resource. Unlike solar and wind energy systems, geothermal resources are mostly buried deep in the earth and aquifers. Even the geothermal resources stored in lakes and rivers can't be visualized.

A few of the more common misconceptions about geothermal energy are listed below:

- ***"It doesn't work."*** Like any new technology, developing design principles, national standards, and a trained workforce has taken several decades to achieve successful installations. With 100 years of open-loop experience and 30 years of closed-loop experience, modern geothermal systems can now provide space heating and cooling for the life of the building.
- ***"It can't be applied everywhere."*** Geothermal energy can be developed everywhere in Ontario, except in the oil and gas fields between Niagara Falls and Windsor and areas of artesian (i.e. flowing) aquifers. However, installing shallow horizontal closed-loop systems is not precluded even in these two conditions.
- ***"It is not sustainable."*** The 8 to 12°C heat in the upper 300 m of the ground is a constant energy resource derived from the earth's molten centre. With proper design, borehole fields and aquifers can be sustained in perpetuity.
- ***"It's too expensive."*** Geothermal energy systems are capital-intensive but have a long life and low operating costs. The economics of geothermal systems should be compared to the life cycle costs of conventional fossil fuel and electrical heating and cooling systems. As the price of natural gas and electricity escalates, the cost of geothermal systems will become more attractive. Financing options like third-party ownership allow geothermal to be the lowest capital cost solution in some markets.
- ***"The installations will cause aquifer contamination."*** The current North American standards developed by the Canadian Standards Association (CSA) emphasize the protection of water supply aquifers. All closed-loop boreholes and open-loop supply and injection wells must be sealed to prevent the entry of surface contaminants. The system owner is responsible for ensuring the field installations comply with the system design specifications and applicable standards.
- ***"The government laws and regulations are too complicated."*** Like any other building industry, government laws and regulations are in place to protect the public and the environment. Development costs and delays for system approvals are minimized once the project team becomes familiar with the laws and regulations. As municipalities become familiar with geothermal systems, these laws and regulations can be simplified and streamlined to promote the safe and efficient use of geothermal technologies.

2.5 The Business Case for the Building Sector

Geothermal feasibility studies are typically done to determine if an installation makes sense. Life-cycle cost analyses provide the best comparison with other heating and cooling systems. Geothermal systems are now being applied to a broad market sector, including institutional, commercial, residential, and industrial buildings.

Historically, building owners interested in long-term sustainable space heating and cooling systems, that save energy and reduced carbon emissions, are good candidates for geothermal energy installations. Over the past decade, a considerable geothermal growth sector has been in residential condo developments. Third-party ownership of the ground heat exchanger has allowed developers to reduce their capital expenditures while providing a stable, low-cost, long-term heating source for condo buyers. Life-cycle and operating costs including fees for the geothermal system are often less than a conventional HVAC system connected to natural gas.

For most new and retrofit buildings, geothermal systems usually provide the most cost-effective option for heating and cooling during the life of a building. Under the current federal, provincial and municipal initiatives, geothermal is expected to achieve a lower carbon footprint than any other renewable energy option.

In general, an investment in geothermal is less attractive for buildings that are not well-insulated and relatively air-tight. These types of buildings incur higher capital costs for large geothermal installations and increased operating costs.

A few examples of the business case for different components of the building sector are given below:

Homeowners

- New homes constructed to meet or exceed modern building code requirements are ideal candidates for geothermal.
- A reliable energy load analysis is recommended to determine the accurate sizing of a geothermal system.
- Urban homes with relatively large lots are good candidates for closed-loop systems.
- Rural homes with productive water supply wells are good candidates for open or closed-loop horizontal systems.

Commercial buildings

- New buildings designed with heat pump technology are the best candidates for geothermal.
- Existing buildings may be suitable candidates for geothermal systems. Many buildings may require minimal additional retrofits to be suitable for switching to geothermal and any building can be suitable with large scale retrofit projects.
- Commercial buildings located above major aquifers are good candidates for open-loop systems.

Government and institutional buildings

- All new and retrofit government buildings are good candidates for geothermal systems.
- Buildings located above major aquifers are good candidates for open-loop systems.
- In urban areas and dense campuses, the lack of open space may limit closed-loop systems to new construction, where borehole fields can be installed beneath the building footprint.

District energy communities and campuses

- College and university campuses converting historic hot water/steam plants are excellent candidates for geothermal district energy systems.
- New residential communities are excellent candidates for geothermal energy systems.
- Existing downtown communities may be feasible candidates for geothermal district energy systems, depending on the space available for closed-loop borehole fields or open-loop wells.

Geothermal utility investors

- Existing, privately owned commercial geothermal systems may be a good investment for private or public utilities.
- New geothermal systems for commercial buildings are an excellent long-term investment for private and public utilities.

3 DESIGN OF GEOTHERMAL ENERGY SYSTEMS

3.1 Integration of Geothermal Energy into Heating and Cooling Systems

In Ontario, geothermal energy is primarily used for heating and cooling buildings. The quantity of energy available ultimately depends on the hydrogeologic conditions and the resource temperature in the surficial 300 m of the earth's crust. The design of geothermal energy systems is structured as follows:

- Perform modelling of the building's heating and cooling energy loads
- Assess the geothermal resources at each project site
- Review of the various methods of harnessing the stored energy
- Consideration of the optimal methods of converting the geothermal energy to useful energy in the building

The typical method of converting the low-grade (8 to 12°C) thermal energy found in Ontario involves coupling it to a heat pump. Today, "geothermal heat pumps" refers to a system that uses the earth, groundwater, surface water, sewer heat, etc., as both a heat source and a heat sink.

What sets "geothermal energy" apart from other types of renewable energy (e.g. solar, wind, tidal, etc.) is that the Earth's reservoir is finite but always available when properly managed. The flow of energy into and out of the reservoir must be properly engineered to prevent exploitation of the geothermal resource. Harnessing the energy resource requires the design of systems to transfer the energy from the earth's reservoir to the building's heating and cooling systems. Conversion of the geothermal energy to useful energy requires heat exchangers, heat pumps, and distribution pipes to convey the heat to and from the point of use.

The main consideration for geothermal designers is to maintain a relative balance of the annual energy extraction from the earth's reservoirs by returning an equal amount of energy to the ground or surface water on a cyclical basis. This approach becomes more critical in areas of dense development, where the geothermal capacity is limited to the property size around each building. Large vertical bored systems will have less resiliency to unbalanced loads than smaller systems where the bore field can be designed to minimize interference between boreholes. Design professionals use industry-standard software such as GLD or others to ensure that the bore field remains properly balanced throughout its life cycle.

A unique aspect of geothermal energy systems is the many sources of stored energy in the earth's ground. These include aquifers, deep foundations, abandoned gas wells, building dewatering systems, mine dewatering, water-filled abandoned mines, sewer heat, ponds, lakes, and rivers. Each heat source and sink requires a hydronic pumping system to transfer the stored energy to the building for heating and cooling purposes.

Once the geothermal energy is pumped into a building, there are many options to distribute the heat and cold. This includes centralized water-to-water systems, distributed heat pumps, and water-source variable refrigerant flow (VRF) systems.

- The centralized system places all the heat pumps in one room and pumps hot or cold water to heat exchangers throughout the building. This system allows simultaneous heating and cooling in different building parts, as needed.
- In distributed systems, the fluid from the geothermal source is pumped directly into a building loop, which supplies individual heat pumps in each zone or room. This allows the heat pumps in different building parts to either extract heat from or inject heat into the geothermal loop.
- VRF technology uses refrigerant piped through the building from a central condensing unit to heads through-out the building. Moving heat through the building using refrigerant is the most energy efficient process to move heat.

All geothermal energy systems utilize hydraulic pumps to circulate a working fluid from the energy reservoir to the building and throughout the building. For closed-loop systems (e.g. boreholes and surface water heat exchangers), relatively small circulation pumps move the fluid through the piping in the energy reservoirs and the building loops. Submersible pumps are required for wells and surface water systems for open-loop systems.

Regardless of the type of geothermal system in use, a considerable amount of the heating load in a large building (or group of buildings) can be sourced from a cooling demand within the building (e.g. heat from cooling the south side can be circulated simultaneously to the north side). In such a case, only the net imbalance between the heating and cooling loads has to be rejected to (or absorbed from) the geothermal resource.

Geothermal district energy systems are being implemented for large-scale heating and cooling schemes (such as institutional and commercial campuses, residential subdivisions, office blocks, etc.). Examples from the early 2020s include a Mattamy Homes subdivision in Markham, a government campus in Ottawa, several university campuses, and Enwave's deep lake cooling system in downtown Toronto (implemented in the early 2000s). Each geothermal district energy system is designed to circulate ambient-temperature water between the source reservoir and the building heat pumps (centralized or distributed).

3.2 System Operations

The operating principles of geothermal systems are relatively simple and straightforward. The earth's heat is captured by pumping systems with few moving parts, no outside exposure, no transportation costs, minor pumping power and little maintenance. Although geothermal energy is considered renewable, high extraction or rejection rates of building heat can cause overheating or overcooling of borehole fields and aquifers. With some simple energy management procedures, geothermal systems will operate successfully for the life of the building.

There are only two mechanical components of a geothermal system:

- pumps to transfer the thermal energy between the geothermal reservoir and the building and
- heat pumps to convert the geothermal heat to useful heating and cooling in the building.

A geothermal energy system's closed and open loop sides require simple controls and a minimum of monitoring. The controls include throttling valves to adjust the pumping rates and a system of thermostats or a building automation system (BAS). The latter operates the fluid flow between the geothermal reservoir and the building. The pump controls can be "ON-OFF" for smaller systems or "variable speed" for larger systems.

The monitoring component of geothermal systems typically includes flow meters, pressure and temperature gauges, and water level sensors (for open-loop systems). Acceptable temperature differentials between the supply and return fluids and the heating/cooling loads of the building generally dictate the geothermal flow rate. The design consultant must develop a clear and concise sequence of operation to allow a smooth transfer of energy from the ground to the building.

3.2.1 Design Parameters – Heating and Cooling Loads of Buildings

Traditional fossil-fuel and electrical heating systems are designed for the coolest and hottest days of the year and require only the peak annual heating loads. Geothermal heating systems require a very different approach since the geothermal energy is constantly transferred between the subsurface resource and the building. The rate and quantity of the energy transfer varies hourly throughout the year.

For closed-loop systems, the geothermal heat pumps can take advantage of the thermal energy storage properties of the earth. The borehole field acts like a thermal battery and stores the rejected summer heat (from cooling the building) in the ground. The stored heat can be extracted the following winter season and transferred back to the building. For open loop aquifers and surface water systems the large mass of water can disperse the rejected warm or cool water within a few tens of metres of the injection point. Ground water movement will greatly impact the operation of vertical closed loop systems and open loop systems and serves to increase the rate of heat dissipation.

Daily heat transfer between the building and the geothermal resource requires hourly modelling of the building's heating and cooling loads. Toronto is located at a latitude where there is usually a reasonable balance between the annual heating and cooling loads. However, the annual building loads are usually cooling-dominant in southern Ontario, while northern Ontario buildings are heating-dominant.

Unbalanced heating and cooling loads can lead to long-term overheating or overcooling of the geothermal resource. This can be avoided by designing load management options that help to achieve a more balanced annual energy load. Opportunities to achieve cost-effective energy balance include snow melt systems, domestic hot water (DHW) heating systems, heating or cooling the building's makeup air system, etc. In the northern perma-frost areas of Ontario, the rejected cold from geothermal heating can be harnessed to maintain frozen-ground conditions beneath the buildings.

3.2.2 Thermal Properties of the Earth and Closed Loop Systems

The key properties of the earth that affect heat transfer in horizontal and drilled closed-loop systems include:

- The subsurface geology;
- The in-situ temperature;
- The thermal conductivity (TC) of the overburden and bedrock;
- The thermal diffusivity (TD) of the geological formations and
- The groundwater flow pattern.

The TC of the subsurface formations refers to its ability to transfer heat by conduction through the overburden and bedrock. The TD measures the actual rate of the heat transfer. For example, when heating is called for in the early winter, the heat stored in the surrounding overburden and rock will be conducted radially toward each borehole.

The higher the values of TC and TD are for a particular soil or bedrock formation, the easier it becomes for heat conduction. For example, the flow of heat away from a borehole is faster in granite bedrock than in clayey overburden, as the clay soil will act more like an insulator.

The layering of the glacial overburden deposits and the horizontal beds of bedrock found in southern Ontario requires pre-design test drilling and TC/TD testing. The borehole log allows geothermal drillers bidding on the project to understand the particular drilling conditions. In addition, the TC/TD testing procedure allows the thermal resistance of the borehole to be measured, which is needed by the closed-loop designer to optimize the borehole design.

3.3 Aquifer Properties for Open Loop Systems

The key properties of aquifers that affect heat transfer in groundwater open loop systems include:

- aquifer conditions (e.g. sand and gravel, fractured/faulted bedrock, confined or unconfined, etc.);
- the groundwater chemistry and microbiology;
- the groundwater temperature;
- the transmissivity (T), hydraulic conductivity (K), and storage coefficient (S) of the aquifer;
- the vertical and horizontal hydraulic gradients (i);
- the aquifer water level;
- the groundwater migration direction and velocity; and
- the groundwater recharge and discharge conditions.

The T of an aquifer is a measure of groundwater flow through a unit width of the full thickness. It is similar to the TC of geological formations, except that T measures water movement through an aquifer by convection.

The groundwater flow rate is determined from the K of the aquifer (TC divided by the aquifer thickness) and the hydraulic gradients. The S of the aquifer refers to the volume of groundwater stored in the open pore spaces. All aquifer properties must be measured in the field by installing test wells and conducting pumping tests.

Heat exchangers and heat pumps transfer the aquifer heat to the building. Historically, heat exchangers' heated or cooled discharge was emptied into streams or storm sewers. Today, the conservation of groundwater resources requires that the heat exchanger discharge be injected back into the same aquifer used for the supply. The pumping and injection process results in groundwater flowing radially into the supply well by creating a “cone of depression” around it. At the injection well, a mound is created in the aquifer, which results in the groundwater flowing radially outward into the sand and gravel or bedrock fractures.

The thermal capacity of an open-loop well system depends mainly on the T, K, and S of the aquifer. High-value aquifers produce the most water with the least drawdown and mounding effects. The most productive aquifers found in Ontario are glacial deposits of coarse sand and gravel and fractured bedrock formations (such as sandstone, limestone and dolostone).

A key requirement in the design of an open-loop well system is the placement of the injection well. It should be located far enough away from the supply well to prevent the warm (or cold) injection water from flowing back toward the supply well. As a result, most open loop systems will require a property large enough to provide a suitable separation between the supply and injection wells. The actual separation can be determined by thermal groundwater modelling and analysis of the heating and cooling loads from the building.

Unlike closed-loop borehole systems, which can be installed below buildings or outside the building footprint, the open-loop wells must be drilled outside the building footprint. They must be accessible for future inspection, well maintenance and replacement of the submersible pump equipment.

The pre-design testing required for large-scale open loop aquifer systems includes the installation of test wells, followed by a series of pumping tests. The results of this field testing are required to confirm the groundwater quality and the available sustainable geothermal energy. In addition, the aquifer properties are required to design the installation and operation of the permanent open-loop system.

Compared to closed-loop borehole systems, the open-loop well option requires more up-front investment in field testing programs and hydrogeological analyses. However, the capital costs of open-loop installations are typically less, provided a high-capacity aquifer is below the building site. Owners, consultants and operators must carefully weigh the regulatory risks and added operations and maintenance costs of open loop systems when choosing this system over closed loop systems.

For open-loop systems that are designed for surface water (including deep rivers, ponds and lakes), the key properties that affect their design include:

- the seasonal temperature patterns, including thermal stratification of the water body;
- surface water flow patterns;
- effect of seasonal change in the water density (e.g. maximum occurs at 4°C) on convection heat transfer;
- water quality characteristics that can clog the heat exchanger equipment with suspended solids, sediment, microbiological growth, algae, etc.; and
- the flow rate and summer/winter temperatures of the discharge water returned to the water body.

Most surface water properties are determined by conducting a general survey of the water body. One of the key impacts that must be addressed for open-loop surface water systems is the thermal effects on aquatic habitats.

Ontario's largest open loop lake system is Enwave’s deep lake cooling system in Toronto. This system pumps cold water from deep in Lake Ontario to cool multiple downtown Toronto buildings.

3.4 Optimum Use of Geothermal Energy

3.4.1 Balanced Energy Loads

The design of a geothermal energy system is fundamentally different from sizing conventional air-conditioning and boiler heating equipment. Gas fired heating systems and conventional air conditioning systems are sized simply to meet peak summer and winter conditions. However, geothermal heat pumps need to be sized to meet both peak conditions and account for the annual energy drawn from the ground. Geothermal systems rely on thermal storage in the ground. As a result, the more balanced the heat extraction/rejection from/to the ground, the more efficient the geothermal system performance will be.

In practice, the annual heating and cooling loads are rarely identical and can change from year to year as the weather and occupancy of the building change. An extreme example of unbalanced loads would be in Ontario’s Arctic climates, where heating requirements dominate buildings. Similarly, large buildings in Toronto and many southern Ontario communities may be dominated by cooling requirements.

The various types of ground heat exchangers have varying capabilities with respect to thermal balancing:

- Horizontal ground heat exchangers and closed lake or pond heat exchangers are minimally affected by imbalance and are normally sized based on peak connected equipment load.
- Open-loop and small vertical closed-loop systems can be affected by imbalance but can be designed to mitigate these effects with increased spacing between wells or boreholes.
- Large vertical closed-loop ground heat exchangers must carefully consider imbalance and account for this in complete system design to ensure they perform optimally for the long term (20+ years).

The challenge for designing sustainable geothermal systems is to try and create balanced loads. Although an unbalanced closed or open loop system may perform very well for the first 5 to 10 years of operation, the system may eventually be overheated or overcooled. In some locations that are underlain by aquifers, the groundwater flow may mitigate the effects of unbalanced heating and cooling loads on the ground temperature.

The most effective and lowest cost option to create balanced loads is to couple additional heating and/or cooling loads to the geothermal system. This can usually be achieved without resorting to conventional cooling towers and boilers, which are inherently more complex.

Some examples of efficient options that can be considered for annual heating and cooling loads include:

- Snow melting on sidewalks, access ramps, parking lots, etc.;
- Heating of swimming pools, including both indoor and outdoor pools;
- DHW heating;
- Arena ice plant heat rejection;
- Heating and cooling of make-up air systems

3.4.2 Matching the Building Loads to the Geothermal System Output

For geothermal space heating and cooling, it is important to note that the loads on a closed or open-loop system differ from the building loads. Matching the heat extraction/rejection from/to the ground will ensure the geothermal system is used to its full potential and allow the optimum transfer of energy to and from the subsurface resource.

The local geological and groundwater conditions play a big part in designing the optimum geothermal energy system. As a result, thorough field testing must be done to determine the potential output of the most appropriate closed or open-loop system. This energy output must match the building loads as closely as possible to reap the economic, environmental and comfort benefits of geothermal installations. Good design treats the building loads and the geothermal output as a single system. Failure to match the building loads with adequate closed or open-loop capacity will lead to system underperformance or unsustainability.

3.4.3 Optimizing the Geothermal Energy Use

The final step in the design of geothermal systems focuses on optimizing the operation and efficiency of the system. All geothermal systems involve the transfer of heated or cooled fluids between the building and the subsurface. This requires pump power. The distribution of the thermal energy throughout the building requires a combination of pump and fan power. When the building heating and cooling loads are unbalanced, the annual heat load on the geothermal system must be balanced with supplementary heating or cooling systems.

The optimization process focuses on creating an efficient, low-maintenance heating and cooling system that capitalizes on the “free” thermal energy stored in the subsurface. The distribution piping is sized to minimize pumping power. Based on geothermal loop temperatures, controls are installed that set the most efficient entering and leaving flow rates. A sequence of operations is developed to maximize the overall performance of the geothermal system.

The challenge for the geothermal system designer is to optimize the transfer of the geothermal energy that can be captured within the plot of land beneath (or beside) the building. Since the total available energy is finite, improper design and operation can lead to overheating or overcooling of the ground and groundwater.

3.4.4 Monitoring and Managing the Geothermal Operation

When properly designed, tested and put into operation, geothermal systems are much simpler to operate than most conventional mechanical heating and cooling equipment. The sequence of controls to operate the geothermal system must be simple, clear, and concise.

The key monitoring requirements for geothermal systems include:

- The fluid flow rate from the closed or open-loop system;
- The temperature of the fluid entering and leaving the closed or open-loop system;

- The water quality of the circulating geothermal fluid (e.g. air entrainment and antifreeze in closed-loop systems and general chemistry and microbiology in open-loop systems);
- Aquifer temperatures in the vicinity of open loop wells and deep earth temperature in the vicinity of closed loop boreholes; and
- Pumping and injection water levels in open loop wells.

An experienced geothermal specialist should conduct an annual review of the monitoring results. Graphs of the hourly flow and temperature data should be prepared to evaluate the system's past performance and assess the yearly energy load balance for the geothermal loop. Analyses of the annual temperature and flow trends will identify potential overheating or overcooling of the geothermal systems and enable the development of mitigating measures.

4 DRILLING

While there are many types of geothermal systems, it is recognized the majority of systems will be vertically drilled systems. These systems can be installed on almost any sized property in most jurisdictions in Ontario.

As noted in the regulations section of this paper, open-loop and closed-loop geothermal systems are currently regulated under separate pieces of legislation. The key determining factor for regulation under O. Reg. 903 is the use of the hole for testing or extraction of groundwater. If groundwater is extracted or rejected to the hole, even for testing or monitoring purposes, the hole is considered a Well and is subject to the rules of O. Reg. 903.

If the hole is not used to extract water but is used as part of a closed-loop heat exchanger then it is considered a borehole and subject to the rules laid out in O. Reg. 98/12. A properly installed vertically drilled system is completely grouted and sealed with a low permeability grout to prevent the mixing of groundwater. In the overburden, the grouted borehole will typically have a lower permeability than the surrounding ground, thus not presenting a preferential pathway for groundwater contamination.

While both open and closed loop systems can use similar installation methods and drilling technologies, the focus of each regulation differs. O. Reg. 903 pertains to the construction of water wells and protects the underlying aquifers as they relate to water and contamination. O. Reg. 98/12 provides specific regulations around the detection of hazardous gas in sub-surface formations and the release of natural gas or hydrogen sulphide to the environment.

4.1 Drilling Methods

Drilling technologies have advanced considerably over the past decades. The current state of the art in Ontario can drill beyond 260 m depths through overburden and bedrock.

In addition to increased depth, angle drilling techniques are currently being employed by some drilling contractors to allow for larger capacity systems while minimizing impacts at the surface. These techniques are particularly useful in retrofit applications where the building footprint and other services limit the size of a conventional vertical bore field.

Common drilling methods used for geothermal drilling in Ontario include:

- Mud/Water-Rotary Drill – standard for drilling in unconsolidated earth and soft rock, and areas where water tables are high. This is a typically lower cost drilling method but is limited in depth.
- Air-Rotary Drill – commonly used in areas of hard rock, and where water table is deep.
- Dual Rotary – used for deep boreholes where a lower rotary drive is used to advance a steel casing through the over burden and an inner drill which is tooled for bedrock is used to advance hole into the underlying bedrock. This method is most cost effective when designing with fewer deeper boreholes.
- Down-Hole Air Hammer – uses a pneumatic hammer with a hardened tool face to crush rock.

Other drilling methods exist which are less commonly used in geothermal or well drilling in Ontario. The drilling method is selected based on geology and soil conditions at the site. System designers must consider the drilling methods, depths and costs in conjunction with the building and site characteristics.

5 GEOTHERMAL REGULATIONS, STANDARDS AND POLICIES

5.1 CSA C448

The Canadian Standards Association (CSA) has had standards for the geothermal industry since 1992. They are updated regularly to address the various advancements in the industry. The current standard was adapted for North American applications in 2016.

The ANSI/CSA C448 Series-16 standard was the first edition of the bi-national series, and it supersedes the previous 2013 and 2002 CSA C448 standards. While following the most current standard edition is recommended, as of 2023, the OBC enforces CSA-C448-13.

The current 2016 standard is titled: *"Design and installation of ground source pump systems for commercial and residential buildings."* The 2016 Series has broadened the scope of the standards to include the following nine different parts:

- ANSI/CSA C448.0, Design and installation of ground source heat pump systems – Generic;
- ANSI/CSA C448.1, Design and installation of ground source heat pumps for commercial and institutional buildings;
- ANSI/CSA C448.2, Design and installation of ground source heat pump systems for residential and other small buildings;
- ANSI/CSA C448.3, Installation of vertical configured closed-loop ground source heat pump systems;
- ANSI/CSA C448.4, Installation of horizontal configured closed-loop ground source heat pump systems;
- ANSI/CSA C448.5, Installation of surface water (including submerged exchangers) heat pump systems;
- ANSI/CSA C448.6, Installation of open-loop systems groundwater heat pump systems;
- ANSI/CSA C448.7, Installation of standing column well heat pump systems; and
- ANSI/CSA C448.8, Installation of direct expansion heat pump systems.

The OBC referenced 2013 standard is titled: *"Design and installation earth energy systems"* and contains 3 Parts:

- CSA C448.0-13 Design and installation of earth energy systems – Generic applications for all systems;
- CSA C448.1-13 Design and installation of earth energy systems for commercial and institutional buildings; and
- CSA C448.2-13 Design and installation of earth energy systems for residential and other small buildings

5.2 Close-Loop Drilling under O. Reg 98/12

In 2012, the Ministry of Environment Conservation and Parks (MECP) introduced legislation regulating vertical, closed-loop borehole drilling across the province. The Ground Source Heat Pump Regulation is known as O. Reg 98/12. No other type of geothermal energy system (e.g. open loops, surface water loops, horizontal loops, energy piles, etc.) is affected by this regulation.

O. Reg 98/12 focuses on measures to take if a geothermal driller encounters hazardous gas while drilling closed-loop boreholes. The regulation requires all geothermal drilling contractors to obtain an ECA (Environmental Compliance Approval) to install vertical closed-loop systems.

Each contractor's ECA must be accompanied by a detailed Work Plan that describes the procedures to be followed if hazardous gases are encountered in overburden and bedrock formations. The risk of encountering hazardous gas is generally limited to portions of southern Ontario underlain by the major gas pools in shale bedrock, and the limestone bedrock formations that contain gypsum.

5.3 Open-Loop Drilling under O. Reg 903

The installation of open-loop water well systems is regulated by O. Reg 903, commonly called the "Wells Regulation." The same regulation applies to all types of drilling activity except closed-loop boreholes. O. Reg 903 sets out the procedures to seal well casings to prevent contamination of groundwater aquifers. It also includes the procedures to follow if the drilling activity encounters artesian (i.e. flowing) aquifers.

The operation of commercial open-loop well systems is regulated by the Ontario Resources Act (ORA) provisions. For example, a Permit To Take Water (PTTW) is required to operate commercial open-loop supply wells. In addition, an ECA is required for the injection wells to return the water to the same aquifer or a nearby surface body of water (if feasible). PTTWs and ECAs require various system operation records to be submitted to the MECP every year.

5.4 CSA B52 – Mechanical refrigeration code

CSA B52 has been an industry standard for mechanical refrigeration since 1939, with twelve editions published. The standard helps reduce the risk of personal injury by outlining the minimum requirements for the design, construction, installation, inspection, and maintenance of mechanical refrigeration systems. This standard applies to geothermal systems when considering a direct earth energy system or when refrigerant can enter an occupied space (e.g. water-sourced VRF system or large chillers).

5.5 ANSI/AHRI/ASHRAE ISO Standard 13526

Standard 13526 consists of two parts and establishes consistent performance ratings of water or brine-sourced heat pumps. Part 1 focuses on water-to-air and brine-to-air heat pumps, while Part 2 focuses on water-to-water and brine-to-water heat pumps. When reviewing product information, it establishes the operating energy efficiency rating (EER) and coefficient of performance (COP) for water loop, ground-water loop, and ground loop in heating and cooling modes.

5.6 Municipal Policies

In Ontario, relatively few municipalities have policies regarding installing geothermal systems. Some municipalities have permitting requirements referencing obsolete certifications (such as CGC Accreditation) and old CSA C448 standard versions that do not meet the Ontario Building Code. Furthermore, municipalities can exercise their right under the Clean Water Act, 2006 to determine if an earth energy system is considered a contaminant transport pathway. If their assessment is determined as such, then the municipality can implement a by-law or planning approval that restricts the use of an earth energy system within a vulnerable area. Geothermal systems planned within these areas, specifically ones that require additional studies, should be examined closely and deemed at high risk of receiving approval.

The following sections list some of the Ontario municipalities that have established regulations or processes around permitting and approving geothermal systems within their jurisdiction.

5.6.1 City of Toronto

A Stand-alone Mechanical (HVAC) permit is required when drilling a borehole with the intent to install piping, and the borehole field is within the boundary of the building footprint. However, a Site Services Permit is required if the borehole field extends beyond the building footprint. The applicable Permit must be obtained before the construction process can begin.

Typical items that are expected in the submission package:

- Site Plan showing the location of the borehole(s), including separation and building footprint.
- Geothermal Technical specifications.
- Confirmation of Driller ECA.
- Borehole schedule showing the number of boreholes and each borehole's depth.
- Thermal Conductivity (TC) Report (if available).
    - Note: A TC test at the site cannot be completed before receiving a Permit.
- Applicable Laws (such as TRCA).
- Commitment to General Review.
- Mechanical drawings showing piping schematic, borehole elevation and piping detail.
- Permit Application Form, including planned drilling start date in the work description.

The City of Toronto anticipates the permit process to take approximately 30 days to complete.

There are also policies regarding the installation, construction and testing of open loop systems within the City of Toronto. These includes a sewer-use discharge permit for open loop testing (other municipalities have similar regulations).

5.6.2 City of Barrie

The City of Barrie sets requirements for environmental assessments and drilling plans before undertaking any geothermal drilling through these policies:

- Deep Drilling Terms of Reference, September 2021
- Drinking Water Protection Policy, September 2021

The policies place requirements for vertical geothermal drilling tests under the O. Reg. 903 as water testing is required. The project must supply a detailed plan outlining a description of the intended borehole/well construction, the anticipated stratigraphy, developed hydrostratigraphic cross-section, a CSA Phase I ESA investigation, CSA Phase II ESA investigation (if there is known potential for contamination based on the CSA ECA Phase I investigation or information from the City of Barrie), risk management plan of the borehole/well construction, field drilling schedule, and a detailed plan for future well decommissioning.

The Drinking Water policy extends the geothermal system requirements beyond the wellhead protection areas and effectively prohibits systems from being drilled beyond the aquitard confining the municipal aquifer.

5.6.3 Region of Waterloo

The Region of Waterloo outlines a set of rules surrounding geothermal activity through their Regional Official Plan. It combines boreholes and wells as one definition, “Geothermal wells,” which includes vertical open and closed loop configurations but excludes horizontal loops with a depth of 5 metres or less and maintains a protective layer over a vulnerable aquifer.

“Geothermal wells” are not permitted in most Wellhead Protection Areas (WHPAs). Their policy utilizes Wellhead Protection Sensitivity Areas (WPSAs), a subcategory of WHPAs, to define what is permitted through eight classifications. Through their policy, “Geothermal wells” are not permitted in WPSA 1, WPSA 2, WPSA 4, and WPSA 6. However, WPSA 3, WPSA 5, WPSA 7, and WPSA 8 may be permitted but are subject to further study. As for Water Intake Protection Zones, “Geothermal wells” are not permitted in Zone 1 and may be permitted in Zone 2 but are subject to further study.

5.6.4 City of Waterloo

The City of Waterloo is a lower-tier municipality of the Region of Waterloo with the same definition of a “Geothermal well” as the Region. Its Zoning By-Law, 2018-050, outlines that no “Geothermal wells” are permitted west of Weber Street. However, some of this area is not within a Wellhead Protection Area.

5.6.5 City of Guelph

The City of Guelph has a unique situation where approximately 97% of the area within the municipal boundary is within a WHPA and vulnerable area. The City outlines the following conditions that would result in not being approved:

- Project location is within a WHPA-A,
- WHPA-B with a Vulnerability Score of 8 or higher, or

- 1 km within a municipal drinking water supply well and within WHPA-B.

If a project does not meet the preceding items, the proposed project can proceed to a review by the City of Guelph's staff, which may require additional information. The City of Guelph will then issue a final decision: prohibited (including reasons), approved, or tentative approval with conditions.

5.7 Recommended Approval Framework

5.7.1 Authorities Having Jurisdiction (AHJ)with respect to Drinking Water Protection

Under the current system and regulations, several municipalities have instituted regulations prohibiting geothermal or vertical geothermal systems in Well Head Protection Areas. The objective of these regulations and the objectives of the recommendations listed below is to protect local drinking water aquifers. Definitions for source water protection terms are provided by the MOECP[9].

It is recommended that AHJs adopt similar sets of regulations across the province that provide clear direction on where geothermal may or may not be installed. It is recommended to utilize existing and publicly available GIS mapping of wellhead protection and vulnerability areas to determine where geothermal would be acceptable. The following three categories are recommended:

Catagory 1: Deep Vertical Geothermal systems are prohibited.

Within Category 1, it is recommended to not allow deep geothermal systems within the following areas:

- Project location is within a WHPA-A,
- WHPA-B with a Vulnerability Score of 8 or higher.

Catagory 2: Further Study is required.

These studies may include the following on a case-by-case basis:

a. Environmental Assessment.

b. Risk Management Plan.

c. ECA for open loop systems (Permission to Take water, and Permission to reject).

[9] https://www.ontario.ca/page/source-protection

Within Category 2, additional study and permission would be required for:

- Open loop systems in all areas.
- Deep closed loop systems in WHPA-C and WHPA-D zones.
- Areas within a Significant Groundwater Recharge Area (SGRA)

Catagory 3: Approved with no additional requirements.

Category 3 systems are systems that present minimal to no risk to the drinking water systems and include:

- All shallow geothermal systems. The current classification of a shallow geothermal system relates to horizontal systems that are buried to a depth of 5m or shallower.
- Any closed loop geothermal system proposed to be installed outside of: WHPA-A, WHPA-B, WHPA-C or WHPA-D.

A further recommendation of this paper is to extend the definition of shallow system to include any system that does not penetrate through any aquitards confining a municipal drinking water aquifer. This recommended provision would allow for all horizontal closed-loop systems and vertical ground heat exchangers installed to a maximum depth that is above the municipal aquifer confining aquitard. These systems are installed in the overburden and due to the nature of the design and depth do not pose a significant threat to the underlying aquifers. The piping material used in geothermal systems is high-density polyethylene and is effectively inert. The heat transfer fluids used (Propylene Glycol or Ethanol-based) are non-toxic and readily decompose in the ground.

5.7.2 Municipalities Responsible for Enforcement of the Ontario Building Code

In addition to harmonizing the drinking water protection rules, aligning requirements around permit applications is further recommended.

5.7.2.1 Commercial Geothermal Systems:

The City of Toronto has recently provided a framework for documentation requirements for permitting a geothermal system. This allows for separate approval of drilling boreholes before the application for a full building permit. It is recommended that permitting offices adopt a similar system to Toronto, as current construction practice often requires drilling the geothermal system before constructing the building itself.

To allow for proper assessment of the geothermal documentation, whether as a stand-alone permit, or a part of a full building permit application, the following documents are to be supplied by the owner or authorized agent:

- Site Plan showing the location of the borehole(s), including separation between the boreholes and the building footprint.
- Geothermal Technical specifications.
- Confirmation of Driller ECA under O. Reg. 98/12 or the inclusion of this requirement in the design drawing or specifications. (For vertical closed loop systems)
- Borehole schedule showing the number of boreholes and each borehole's depth.
- Thermal Conductivity Report (if available).
    - Note: A TC test at the site may not be completed before receiving a Permit.
- Review of Applicable Laws and other Authorities Having Jurisdiction
    - This includes showing the system is allowable under The Clean Water Act, 2006.
    - Conservation Authority Regulation limits and permits
- Commitment to General Review.
- Geothermal design calculation summary report
    - Must use calculation software which includes an hourly calculation and indicates system operation over a minimum 20-year operating period.
- Mechanical drawings showing piping schematic and details.
- Permit Application Form, including planned drilling start date in the work description.

A qualified Professional Engineer must prepare the above documentation for any systems except those serving buildings under Part 9 of the OBC. The intent of the above is to ensure the geothermal system meets the requirements of CSA C448.1-2013 as referenced under the Ontario Building Code (and to be adopted NBC 2020). A sample checklist is provided in Appendix A – Geothermal Feasibility Checklist.

5.7.2.2 Residential & Small building Geothermal Systems

Systems serving buildings under Part 9 of the OBC should provide the information below:

- Site Plan showing the location of the borehole(s), including separation and building footprint.
    - Site plan shall include other services to the building
    - Indicate borehole depth
- Confirmation of Driller ECA under O. Reg. 98/12 or the inclusion of this requirement in the design drawing or specifications. (For vertical closed loop systems)
- Review of Applicable Laws and other Authorities Having Jurisdiction
    - This includes showing the system is allowable under The Clean Water Act, 2006.
    - Conservation Authority Regulation limits and permits.
- HVAC drawings and calculations prepared by an individual with BCIN qualifications.
    - These drawings must indicate heat pump selection and rated capacities.
    - Installation details for small systems consisting of less than three heat pumps on a single ground loop can be provided with manufacturer installation guides.
- Geothermal design calculation summary report
    - Prepared by a Certified Residential Designer.
- Permit Application Form, including planned drilling start date in the work description.

As with other requirements under part 9, a Professional Engineer is not required to prepare the design documentation. It is recommended that individuals trained in the design of residential geothermal systems provide the geothermal-specific documentation listed above. Refer to section 6.2 for recommended training.

6 GEOTHERMAL TRAINING

6.1 Installation

6.1.1 The IGSHPA Geothermal Accredited Installer Course

This course is offered through HRAI and includes topics such as:

- Design and Material Options
- System Layout
- Pipe Joining Techniques - for butt, socket, saddle and electrofusion
- Trenching/Drilling Processes
- Air and Debris Purging
- Pressure Drop Calculations
- Pump and Fluid Selection
- Thermal Conductivity
- Start-up, Performance Checking & Troubleshooting

Upon successful completion of the corresponding exam, IGSHPA Accredited Installer certification will be provided.

This course and certification are recommended as a requirement for:

- *Residential HVAC and Geothermal loop installation contractors*
- *Commercial Geothermal loop installers*

6.2 Design

The courses listed in the following sub-sections of the this paper provide specific geothermal training to industry professionals. In addition to these training courses, a number of colleges and universities in Ontario currently off programs and classes related to various aspects of geothermal installation. These include:

- Fleming College – Resources Drilling Technician Program - https://flemingcollege.ca/programs/resources-drilling-technician

- Multiple Colleges – Renewable Energies Technician - https://www.ontariocolleges.ca/en/programs/energy-environmental-and-natural-resources/energy-systems?q=geothermal&page=0

6.2.1 IGSHPA Certified Residential Geothermal Designer Course

This course is offered through HRAI and teachs how to properly design a residential system, starting with the benefits and types of ground source heat pumps. Attendees will also learn about the following:

- Design process;
- Energy Loads and Requirements;
- How to calculate loads;
- How to select mechanical systems;
- Site, geology and soil conditions;
- Ground heat exchanger design;
- Pumping, interior piping and header design;
- Economics of the design;
- Calculate a sample problem.

An IGSHPA Certified Residential Geothermal Designer certification will be issued after successfully completing the corresponding exam.

This course and certification are recommended as a requirement for:

- *Residential HVAC and geothermal loop contractors*
- *BCIN registered residential HVAC designers*

6.2.2 Certified GeoExchange Designer (CGD) Course

This course is offered through IGSHPA and other third-party trainers. It is a prerequisite to become a certified GeoExchange Designer, which is recommended for commercial geothermal system design.

This design course is created for professional engineers, registered architects, installers, and contractors. This course is essential for individuals wanting advanced training and experience in designing GSHPs and is required for experienced individuals who wish to earn certification. Course topics include:

- Ground source heat pump design – Residential & Commercial;
- Designing closed loop, ground heat exchanger, configurations & layouts;
- Soil/rock classification and conductivity;
- Borehole grouting;
- Thermal conductivity in-situ testing
- Ground loop heat exchanger software
- Ground source heat pump in system performance

This course and certification are recommended for the following:

- *Commercial Geothermal Designers*

6.3 Inspection and Plans Examiners

An Ontario-centric inspection course is currently not offered. IGSHPA currently provides a 2-day Inspector course with the following topics:

- GSHP System Benefits;
- IGSHPA Standards, ASHRAE and NGWA Guidelines;
- Local and State GSHP Codes;
- Outside Heat Exchange Configurations;
- Building Site and Loop Field Layout;
- Heat Fusion and Antifreeze Solutions;
- System Startup and Commissioning;
- Sample Inspection forms and checklists;

This document, along with appendices and referenced codes and standards, should be used to supplement the information provided in the course to allow plan examiners and inspectors to properly assess geothermal system designs and requirements.

This course and certification are recommended as a requirement for:

- *Plans Examiners*
- *Municipal Inspectors*

GLOSSARY

The terms below are defined in the documents referenced. In the case where different definitions are provided, both definitions and references are shown. If no reference is shown, the term is defined in this document only.

Antifreeze – "a modifying agent added to water in closed-loop systems to lower its freezing temperature." (CSA Group, 2013)

Aquifer – "an underground layer of permeable subsurface materials (e.g. sand, gravel, fractured rock, etc.) capable of yielding significant ground water." (CSA Group, 2013)

– "a water-bearing formation that is capable of transmitting water in sufficient quantities to serve as a source of water supply." (Government of Ontario, 2020)

Aquifer thermal energy storage (ATES) – "underground thermal energy storage where an aquifer is the thermal store and the heat transfer medium is groundwater." (CSA Group, 2013)

Aquitard – "an almost impermeable underground layer of the subsurface (e.g. clay, silt, un-fractured rock, etc.) that does not transmit significant quantities of groundwater." (CSA Group, 2013)

Authority Having Jurisdiction – "a federal, provincial, or municipal ministry, department, board, agency, or commission that has responsibility for regulating by statute the use of products, materials, or services within its jurisdiction." (CSA Group, 2013)

Balancing – "the proportioning of flows within an air-, liquid-, or water-distribution system according to the design." (CSA Group, 2013)

Bedrock – "a solid aggregate of minerals underlying the overburden or outcropping at surface." (CSA Group, 2013)

– "the solid rock underlying unconsolidated material such as gravel, sand, silt and clay, or solid rock at the ground surface." (Government of Ontario, 2020)

Borehole – "a vertical, horizontal, and/or diagonal hole drilled into the overburden or into the bedrock." (CSA Group, 2013)

Borehole Heat Exchanger – "a ground heat exchanger installed in a borehole." (CSA Group, 2013)

Borehole thermal energy storage (BTES) – "underground thermal energy storage in which the subsurface is the thermal store and the heat transfer medium is a heat-transfer fluid in a borehole heat exchanger." (CSA Group, 2013)

Building Loop (or indoor piping) – "piping that connects the heat pump equipment in the building to the ground heat exchanger after the transition between the ground heat exchanger piping or ground heat exchanger manifold inside the building." (CSA Group, 2013)

Dewatering Well – "a well that is not used or intended for use as a source of water for agriculture or human consumption and that is made, to lower or control the level of ground water in the area of the well, or to remove materials that may be in the ground water." (Government of Ontario, 2012)

Earth Energy System – "a heating and cooling system for buildings or structures that uses a fluid to exchange heat with the ground or water. An earth energy system is also referred to as low temperature geothermal system or ground source heat pump. Earth energy systems should not be confused with high temperature geothermal systems (over 50 degrees Celsius) that obtain heat from deep within the earth to produce heat." (Ontario Ministry of Environment, 2013)

Ground Heat Exchanger – "a continuous, sealed, underground heat exchanger consisting of a closed-loop through which a heat-transfer fluid passes to and returns from a heat pump." (CSA Group, 2013)

Ground-Source Heat Pump – "a system that is designed to heat and cool a building or structure by using a heat-transfer fluid to exchange heat with the ground or ground water." (Government of Ontario, 2012)

Ground-Coupled Heat Pumps – "are closed-loop piping systems buried in the ground. They are further subdivided according to ground heat exchanger design: vertical and horizontal." (Kavanaugh & Rafferty, 2014)

Ground-Water Heat Pumps – "are open-loop piping systems with water wells." (Kavanaugh & Rafferty, 2014)

Heat Pump – "a refrigeration system used to transfer heat into a space or substance." (CSA Group, 2013)

Hole – "includes a vertical or diagonal hole made in the ground for the purposes of installing a "well" as defined in the Ontario Water Resources Act as part of an open loop earth energy system or sole purpose of installing heat transfer fluid tubing as part of a closed loop or direct exchange earth energy system." (Ontario Ministry of Environment, 2013)

Overburden – "unconsolidated sedimentary deposits that are variable in thickness or discontinuous, and overlying the bedrock." (CSA Group, 2013)

– "unconsolidated material overlying bedrock." (Government of Ontario, 2020)

Shallow Ground Heat Exchanger - is a horizontal or vertical closed loop that does not penetrate the first aquitard or is within 5m of the surface.

Surface-Water Heat Pumps – "are closed-loop piping coils or open-loop systems connected to lakes, streams, or other reservoirs." (Kavanaugh & Rafferty, 2014)

Test Hole – "is made to test or to obtain information in respect of ground water or an aquifer, and is not used or intended for use as a source of water for agriculture or human consumption." (Government of Ontario, 2020)

– "a well that, is made to test or to obtain information in respect of ground water or an aquifer, and is not used or intended for use as a source of water for agriculture or human consumption." (Government of Ontario, 2012)

Thermal Conductivity (TC) Test - provides a way to determine the ground's overall resistance to heat flow by inversely determining the thermal conductivity, diffusivity, and temperature. (ASHRAE, 2019)

Vertical Closed Loop Ground Source Heat Pump – "a ground source heat pump that uses a continuous, sealed, underground heat exchanger consisting of subsurface tubing through which the heat-transfer fluid passes." (Government of Ontario, 2012)

Well – "a hole made in the ground to locate or to obtain ground water or to test or to obtain information in respect of ground water or an aquifer, and includes a spring around or in which works are made or equipment is installed for collection or transmission of water and that is or is likely to be used as a source of water for human consumption." (Government of Ontario, 2021)

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APPENDIX A – GEOTHERMAL FEASIBILITY CHECKLIST

This checklist provides a representation of how municipalities can integrate geothermal projects into their building permitting process and is not an exhaustive list of all the requirements. This checklist does not guarantee that a proposed project conforms to all the requirements of CSA C448.1-13, Building Code, or local requirements. No guarantee is made that all permitting bodies will accept these interpretations. Any use or reliance on this form by a third party is solely the responsibility of said third party.

Y	N	N/A	Section	Description	Comments
			Siting	Is the project located in a Wellhead Protection Area (WHPA)? If so, confirm if the project meets the requirements to proceed or is not permitted based on the applicable by-laws or approval process of the authority having jurisdiction (AHJ).	
				Is the project located in a Water Intake Protection Zone? If so, confirm if the project meets the requirements to proceed or is not permitted based on the applicable by-laws or approval process of the AHJ.	
			CSA C448.1-13, 4. General	**4.1 - Designed by a Professional Engineer:** A Professional Engineer is licenced by the Professional Engineers of Ontario (PEO) to perform engineering work in Ontario.	
				4.2 - All work performed by designated trades meets local requirements: Trades include but are not limited to, refrigeration, sheet metal, plumbing, and electrical. All work is to be conducted by qualified personnel.	
				4.3 Property and Access: Permission received if the project extends into, cross or interfere with the equipment or rights-of-way of utilities, jurisdictions, and other property owners.	
			CSA C448.1-13, 5.	**5.2 - Heat pump unit requirements:** Heat pump equipment must meet the requirements of CSA C22.2 No. 236 and CSA-C13256-1 or CSA-C13256-2.	

Y	N	N/A	Section	Description	Comments
			Equipment & Materials	**5.3 - Underground Piping Requirements:** If using polyethylene pipe and fittings, the requirement is to meet CSA B137.1 and 5.3.2.1, 5.3.2.2, 5.3.2.3 of CSA C448.1-13. If using crosslinked polyethylene (PEX) pipe and fittings, the requirement is to meet CSA B137.5 and 5.3.3.1, 5.3.3.2 of CSA C448.1-13.	
				5.5 - Indoor Piping Requirements: Piping and materials are specified to meet CSA C448.1-13 clause 5.5.	
				5.6 - Pipe and fitting on-site storage: Piping and materials are specified to meet CSA C448.1-13 clause 5.6.	
				5.7 - Heat Transfer medium: Specified to meet the requirements of Clause 5.7 of CSA448.1-13.	
				5.7.2 - Refrigeration requirements: Heat transfer fluid complies with CSA B52 or ANSI/ASHRAE 34.	
				5.8.1 - Drilling: specifications in compliance with CSA448.1-13 clause 5.8.1.	
				5.8.2 - Excavating: specifications in compliance with CSA448.1-13 clause 5.8.2.	
				5.8.3 - Grouting: specifications in compliance with CSA448.1-13 clause 5.8.3.	
				5.8.4 - Backfilling: specifications in compliance with CSA448.1-13 clause 5.8.4.	
			CSA C448.1-13, 6. Site Requirements	**6.1.1 - General site survey requirements:** An engineer or geologist with expertise in groundwater conducts a site survey that meets CSA448.1-13 clauses 6.1.2 and 6.1.3.	
				6.1.2 - Site Survey: Identify physical limitations and conduct a subsurface investigation based on the energy earth system configuration (CSA C448.1-13 clauses 6.2, 6.3 or 6.4).	
				6.1.3 - Water well and geological records review: All available records have been reviewed, and any issues have been documented. To be carried out by an engineer or geologist.	

Y	N	N/A	Section	Description	Comments
				6.5 - Geological report: a report prepared by an engineer or geologist with expertise in groundwater summarizing the findings of all requirements within this clause.	
			CSA C448.1-13, 7. Design Requirements	**7.1.1 - Design Considerations:** The design algorithms meet Clause 7.1.1 of CSA C448.1-13 requirements.	
				7.1.5 - Design Considerations: All applicable notes in Clause 7.1.5 of CSA C448.1-13 shall be included.	
				7.2.1.1 - Designed by an engineer: Ground heat exchanger design must be completed using acceptable design algorithms/software.	
			CSA C448.1-13, 8. Installation Requirements	**8.1 - GHX Installation:** Specifications and drawings contain requirements for installing the GHX loop according to CSA C448.1-13. Where applicable, additional manufacturer requirements are to be included.	
			CSA C448.1-13, 9. GHX Testing Requirements	**9.1 - GHX Testing:** Specifications and drawings contain requirements for verifying the GHX loop according to CSA C448.1-13. Where applicable, additional manufacturer requirements are to be included.	
			CSA C448.1-13, 10. Distribution System	**10.1 - Good Practice:** Distribution systems vary widely (and also fall under other requirements); as such, it is expected that good practices are followed, and notes in 10.1 through 10.2 are taken into consideration.	
			CSA C448.1-13, 12. Startup & Delivery	**12 - Startup and delivery:** Clauses 12.1 to 12.4 are fulfilled before turn-over and are explicitly referenced in the specification documents.	
			CSA C448.1-13, A. Environmental Guidelines (Informative)	**A2.1.1 - Recommended Environmental Concerns:** Clauses in A.2.1 are taken into consideration if not already pertaining to a mandatory provision in CSA C448.1-13.	